A STUDY OF TRACE-ELEMENT PARTITIONING BETWEEN PYROXENE AND ANGRITIC MELT: EQUILIBRIUM AND KINETIC EFFECTS INCLUDING SECTOR ZONING IN PYROXENE. G. E. Lofgren[1], A. J. Fahey[2], and G. J. Wasserburg[2], [1]Mail Code SN4, NASA Johnson Space Center, Houston TX 77058, USA, [2]Lunatic Asylum, Division of Geological and Planetary Science, Mail Stop 170-25, California Institute of Technology, Pasadena CA 91125, USA.

As part of an ongoing effort to determine partition coefficients, D, for relevant planetary materials, we have determined Ds for REE and Sc, V, Rb, Sr, Y, Zr, Nb, Ba, Hf, Th, and U between fassaitic pyroxene and melt. We have focused on both equilibrium and kinetically controlled partitioning and the application of the data to the petrogenesis of angrites. We used the synthetic ADOR starting material studied by [1], which was doped with trace elements at levels of 2 to 600 ppm The experiments were conducted in 1-atm, gas-mixing furnaces with the O fugacity fixed at 1.2 log units above the iron-wüstite buffer. Equilibrium experiments were equilibrated at 1225°C for 24 hr (ADE-103, 104) and the dynamic crystallization experiment was cooled directly from just above the melting temperature of 1265° to 1000°C at 5°C/hr (ADE-106). Trace-element abundances were measured with the PANURGE ion microprobe using the techniques and standards of [2].

The equilibrium Ds from ADE 103, 104 compare well with the data on REE determined by [3] considering the differences in the compositions of the angrite melts studied. McKay et al. [3] point out that the Kds for fassaite do not differ significantly from diopside [4], and our data are even closer to the diopside values. Green [5] reviews recent experimentally determined Ds for calcic pyroxene and our data compare well, although there are a few exceptions. The Ds for the heavy REE are slightly lower than those determined by Hart and Dunn [6] in a basaltic system. It is unexpected that this fassaitic pyroxene should compare so well with the normal calcic pyroxenes.

In the cooling experiment, ADE-106, the REE and most of the other trace elements are enriched in the pyroxene as the Fe content increases, as in normal igneous zoning. The Ds at the Fe-rich rims are systematically lower than the equilibrium values determined near the liquidus. This may be in part attributable to the crystallization of matrix phases that further enriched the residual melt in the incompatible elements, but we feel that the Fe-rich melt is also important. The normal and sector zoning in the fassaite have been documented by X-ray maps produced on a Cameca SX100 microprobe. The sector zoning is most apparent for Ti and Al and ion probe analyses in different sectors show that REE are enriched in Al-rich sectors. The normal zoning is evident in Mg and Fe and there is a normal zoning trend in the REE with the LREE elements showing a more pronounced increase with increasing Fe/Fe + Mg. The closed system fractionation trends, seen in these experiments and also in LEW 86010, are consistent with the igneous history suggested for that meteorite [3,7].

Kirschsteinite and a rhonitelike mineral have crystallized as matrix phases in ADE-106, along with spinel. The kirschsteinite has a complex intergrowth of Ca-rich and a Ca-poor zones, and both have strongly LREE-depleted patterns that resemble those in LEW 86010 [7]. The REE and trace elements are enriched in the Ca-rich zones. The rhonitelike mineral has a flat REE pattern almost indistinguishable from the melt.

References: [1] Lofgren G. E. and Lanier A. B. (1992) *EPSL, 111*, 455–466. [2] Kennedy A. K. et al. (1993) *EPSL, 115*, 177–195. [3] McKay G. A. et al. (1994) *GCA, 58*, 2911–2919. [4] Grutzeck M. et al. (1974) *GRL, 1*, 273–275. [5] Green T. H. (1994) *Chem. Geol., 117*, 1–36. [6] Hart S. R. and Dunn T. (1993) *Contrib. Mineral. Petrol., 113*, 1–8. [7] Crozaz G. and McKay G. (1990) *EPSL, 97*, 369–381.

GRAPHICAL ANALYSIS OF ANGRITE PETROGENESIS. J. Longhi[1], A. J. G. Jurewicz[2], D. W. Mittlefehldt[3], and J. H. Jones[4], [1]Lamont–Doherty Earth Observatory, Palisades NY 10964, USA, [2]U.S. Synthetic Corporation, 744 South 100 East, Provo UT 84606, USA, [3]Lockheed Engineering and Sciences Company, Mail Code C23, 2400 NASA Road 1, Houston TX 77058, USA, [4]Mail Code SN4, NASA Johnson Space Center, Houston TX 77058, USA.

Experiments [1] have shown that partial melting of devolatilized carbonaceous chondrite source regions can produce eucritelike liquids at low-fO_2 (IW–1) and low-SiO_2, angritelike liquids at higher fO_2 (IW + 2). The reason for this different behavior is reduction of ferrous iron at the lower fO_2, which changes the normative character of the silicate source. Although the low fO_2 experiments produced liquids closely resembling known eucrites, the match between liquids from the "high" fO_2 runs and known angrites was not as close and aluminous augite (fassaite), a key mineral in angrites, was observed only at the solidus.

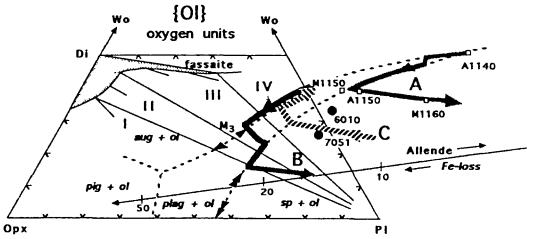

Fig. 1.

Figure 1 is a depiction of the olivine liquidus surface projected from the olivine component with boundary curves drawn to agree with the liquid data (open squares) of [1]. The diopside solid solution field is taken from the data of [2,3] in the CMAS system as an approximation. These latter data show a dramatic increase in Al_2O_3 concentrations in coexisting diopside as SiO_2 in the liquids decrease (~3% Al_2O_3 in di at the thermal divide M3 increasing to 10.5% (= fassaite) near the liq + ol + di + an + sp invariant point). Tielines between diopside (augite) and anorthite divide the diagram into a number of potential partial melting fields (I–IV). Bulk compositions in field I will begin melting at the liq + ol + di + an + opx invariant point; those in field IV begin melting at the liq + ol + di + an + sp point; and those in fields II and III begin melting along the liq + ol + di + an boundary curve. These latter melts will have crystallization paths in opposite directions as determined by the M3 thermal divide. A vector, cutting across the melting fields, shows the direction and magnitude of Fe loss from an Allende-like source. The heavy shaded curve A shows the "high" fO_2 Allende/Murchison melting path from [1], which passes to the low-silica side of the LEW angrites [4]. A second shaded curve (B) shows the melting path for an Allende-like source that has lost ~15% of its FeO. Curve C shows the fractional crystallization path of a partial melt from an Allende-like source with ≤10% FeO loss. Clearly, liquids along this path would closely match the compositions of the LEW angrites (±ol) and would crystallize fassaite after ol + sp (optional) and ol + an.

References: [1] Jurewicz A. J. G. et al. (1993) *GCA, 57*, 2123–2139. [2] Longhi J. (1987) *Am. J. Sci., 287*, 265–331. [3] Libourel G. et al. (1989) *Contrib. Mineral. Petrol., 102*, 406–421. [4] Mittelfehldt D. W. and Lindstrom M. M. (1990) *GCA, 54*, 3209–3218.

PHASE DECOMPOSITION IN THE IRON-RICH IRON-NICKEL-SULFUR SYSTEM FROM 900°C TO 300°C—APPLICATION TO METEORITIC METAL. L. Ma[1], D. B. Williams[1], and J. I. Goldstein[2], [1]Department of Materials Science and Engineering, Lehigh University, Bethlehem PA 18015, USA, [2]College of Engineering, University of Massachussetts, Amherst MA 01103, USA.

It has been observed that metal particles in ordinary chondrites contain essentially no P and that the tetrataenite rim of the metal particles is much wider than that in other types of meteorites, especially when the taenite rim abuts troilites (FeS) [1]. It is possible that S plays an important role in the formation of the zoned tetrataenite at low cooling temperatures.

Most of the studies of the Fe-Ni-S system have concentrated on the high-temperature and high-Ni/high-S part of the ternary diagram [2,3]. In this study we have systematically investigated the microstructure and microchemistry of the Fe-rich Fe-Ni-S system in regions where meteoritic metal forms from 900°C down to 300°C. High-spatial-resolution electron probe microanalysis (EPMA) and analytical electron microscopy (AEM) techniques were employed. The two- and three-phase boundaries at high temperatures (900°C to 600°C) are consistent with previous studies. However,